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OPTIMIZATION OF CUTTING PARAMETERS IN MILLING OPERATION TO IMPROVE SURFACE FINISH OF EN 31

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ABSTRACT
Present work includes understanding the effects of various milling parameters such as spindle speed, feed rate, depth of cut and coolant flow on the surface roughness (Ra) of finished products. The experimental plan was based on Taguchi's technique including L9 orthogonal array with four factors and three levels for each variable and studying the contribution of each factor on surface roughness. The experiments were conducted on EN31 material on CNC vertical milling machine using carbide inserts. The analysis of mean and variance technique is employed to study the significance of each machining parameter on the surface roughness. The results indicated that cutting speed with the contribution of 60.69% is the most important parameter in controlling the surface roughness, followed by spindle speed. The optimal parameters for surface roughness is obtained as spindle speed of 1150 rpm, feed rate of 175 mm/min, 1.0 mm depth of cut, 20 lit/min coolant flow.

INTRODUCTION
The objective of this project work is to find out the set of optimum values for the selected control factors in order to reduce surface roughness using Taguchi's robust design methodology and to develop the prediction models for surface roughness considering the control factors. In the present work, Taguchi method is used to determine the optimum cutting milling parameters more efficiently. Four control factors viz. cutting speed, feed rate, depth of cut and coolant flow are investigated at three different levels. The work piece material used is EN-31 steel alloy. Taguchi method is used to optimize the process parameter i.e. surface roughness using signal-to-noise ratio for milling process of the work piece materials. Experiments are carried out using L9 (3^4) orthogonal array.

MATERIALS AND METHODS
Milling Process
Milling is the process of removing extra material from the work piece with a rotating multi-point cutting tool, called milling cutter. The machine tool employed for milling is called milling machine. Milling machines are basically classified as vertical or horizontal. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type. Most milling machines have self-contained electric drive motors, coolant systems, variable spindle speeds, and power-operated and table feeds. The three primary factors in any basic milling operation are speed, feed and depth of cut. Other factors such as kind of material and type of tool materials have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine

Surface Roughness
Surface roughness is an important measure of product quality since it greatly influences the performance of mechanical parts as well as production cost. Surface roughness has received serious attention for many years and it is a key process to assess the quality of a particular product. Surface roughness has an impact on the mechanical properties like fatigue behavior, corrosion resistance, creep life, etc. It also affects other functional attributes of parts like friction, wear, light reflection, heat transmission, lubrication, electrical conductivity, etc. Surface roughness of turned components has greater influence on the quality of the product. Whenever two machined surfaces come in contact with one another the quality of the mating parts plays an important role in the performance and wear of the mating parts. The height, shape, arrangement and direction of these surface irregularities on the work piece depend upon a number of factors such as:

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A) The machining variables which include

- Cutting speed,
- Feed and
- Depth of cut.

B) The tool geometry

Some geometric factors which affect achieved surfaceroughness include:

- Nose radius,
- Rake angle,
- Side cutting edge angle and
- Cutting edge.

C) Work piece and tool material combination andtheir mechanical properties

D) Quality and type of the machine tool used,

E) Auxiliary tooling and lubricant used and

F) Vibrations between the work piece, machine tooland cutting tool.

LITERATURE SURVEY

Literature review bridges the gap between two stages of a project execution i.e. problem definition and evolution of design configuration (Solution). Extensive literature review is carried out to explore the elements of the present project requirement

GuruvaiahNaidu,Venkata Vishnu, JanardhanaRaju used Taguchi method to determine the optimum cutting milling parameters more efficiently. Four control factors viz. cutting speed, feed rate, depth of cut and coolant flow are investigated at three different levels. The work piece material used is EN-31 steel alloy. In the present experimentation the optimum speed obtained using tauguchi technique is 1094rpm. Similarly the results obtained for feed and depth of cut are 100m/min and 1mm respectively. The corresponding Optimum coolant flow is 90 lts/min.[1](2014)

BombaleRavindra Ramesh, V. L. Kadlag, D. R. Mahajanclaim that feed rate is the most important factor influencing surface roughness in machining of alloy steels. Apart from feed rate, the other parameters such as coolant flow and tool materials were also found to be significantly affecting surface roughness in respective case studies.[2](2016)

MihirThakorbhai Patel concluded that Milling machine is superior to other machine as regards accuracy and better surface finish Spindle speed, feed rate and depth of cut are the important parameters while studying the effects of process parameters on the required responding characteristics. Taguchi methodology widely used for the single optimization[3](2015)

Mahendra M S , B Sibin studied the optimal cutting condition for face milling was selected by varying cutting parameters such as cutting speed, feed rate and depth of cut and response parameter as surface roughness through the Taguchi Parametric design. The experimental results indicate that in this study the effects of spindle speed and feed rate on surface were larger than depth of cut for milling operation[4](2016)

S.KarthikheyenPujarikothanda Ramamurthy Used Taguchi analysis, the effect of various process parameters at different levels on face milling is analyzed . The optimum levels of control factors are found as under:Cutting speed: 1000 rpm Feed rate :150 mm/min Depth of cut :2 mm. The predicted optimum MRR level is 23.97 gms/min, reflecting higher yield level using this optimization. The optimum level of control factors as above are the levels at which the effect of noise factors on the response parameters is less.[5](2016)

G.HarinathGowda, M. VenugopalGoud , K. DivyaTheja , M. GunasekharReddyfinding the optimal process parameters for turning process of EN-31 In Matlab software, ANN module is available which is used to predict

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the relationships of input process parameters and the output variables It is found that the speed and the depth of cut have great significance on the force and Temperature, whereas the feed has less significance on both the outputs.[6](2014)

Milan Kumar Dasa, KaushikKumarb, Tapan Kr. Barmana and PrasantaSahooainvestgated the optimal combinations of process parameters in ECM of EN 31 steel for maximum material removal rate (MRR) and minimum surface roughness (Ra). Experiments are carried out to establish an empirical relationship between process parameters and responses using response surface methodology (RSM). Electrolyte concentration and feed rate and voltage are the most significant parameters on responses[7](2014)

Milan Kumar Dasa, KaushikKumarb, Tapan Kr. Barmana and PrasantaSahooa investigates the effect of process parameters on material removal rate (MRR) and surface roughness characteristic and parametric optimization of process parameters in ECM of EN31 tool steel Thus, grey-based Taguchi method optimizes the process parameters fairly well. ANOVA reveals that electrolyte concentration has the maximum influence on metal removal rate and surface roughness characteristics.[8](2014)

Vijay Arora, GurpreetIqbalSingh describes the tool life prediction model with end milling EN31 tool steel using P30 Tungsten uncoated carbide tool. The data set from the Taguchi method design is taken. For discussion the effects of cutting speed, feed rate and depth of cut on tool life of P30 are considered. This paper suggests a novel technique for the tool wear measurement based on machine vision. Tool images are captured with cutting operations using a machine vision system for the analysis. The proposed scheme is shown to be effective for the tool wear prediction. The use of the EN31 give the different and optimum parameters. The wear mechanisms of cutting tools made of EN31 were investigated.[9](2014)

Prof. M.B. Sorte, HeenaShaikh Optimization of milling parameters has been carried out in the literature by many researchers. A few works are based on simulations and other works are based on many experimental runs, collecting huge amount of data and processing it to achieve the result. Taguchi method is widely adopted in the literature for the improvement of quality and machining economics. Taguchi method uses the orthogonal array concept with small number of experimental runs to investigate the effects of parameters on performance measures reduces the sensitivity due to inherent variations present in the system. Moreover, Taguchi method does not consider the interactive effects of control factors. Research work on Multi response optimization requireattention.Very less work is done on MRPI. Also other methods of optimization should be used. Output parameter such as surface roughness is focused much other parameters such as tool life, toolwear, ,cutting force, torque, flank angle, approach angle, power generated etc.[10](2015)

ArshadQureshi 1, Madhukar Sorte2, S.N. Telioptimized the cutting parameters such as feed rate, depth of cut and cutting speed for the turning process of AISI P20 steel (mould steel) for better surface finish. Taguchi's technique has been used to accomplish the objective of the experimental study. L-9 Orthogonal array, Signal to noise (S/N) have been used for conducting the experiments

EXPERIMENTAL SETUP AND DESIGN

The aim of the present work is to find out the set of optimum values for the selected control factors in order to reduce surface roughness using Taguchi's Robust Design Methodology. The work material selected is EN - 31steel alloyThe experiments are conducted using L9 (3^4) orthogonal array.

MILLING MACHINE

The milling operations are carried out on a CNC milling. The machining tests a r econducted under the different conditions of Cutting speed, Feed rate, Depth of cut and coolant flow. The experiments are conducted at Government Polytechnic Thane and the machine tool used is HAAS CNC VERTICAL MILLING MACHINE.

WORKPIECE MATERIAL

The work piece material used is EN-31 Steel belongs to steel alloy of 50mm long,50mm breadth and 15mm thickness in the form of plates. The EN-31 defined a number of Emergency Number Steel alloy standards with a numbering scheme for easy reference and are mentioned them in the form of grades. In the present experiment the material used isEN-31 Steel, which is a Steel alloy. EN-31 Steel alloy consisting of 1.08% of carbon, 0.25%

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of silicon, 0.53% of manganese, 0.015% sulphur, 0.022% phosphorus, 0.33% of nickel, 1.46% of chromium, and 0.06% of molybdenum .

Table No.1: Chemical CompositionOf EN-31

Element	Element Chemical Composition (wt%)
C	1.08 %
Si	0.25 %
Mn	0.53 %
S	0.015 %
P	0.022 %
Ni	0.33 %
Cr	1.46 %
Mo	0.06 %

Fig No.1 Work Pieces Used For Machining

Table No2: Mechanical Properties of EN-31

Tensile strength	750 N/mm²
Yield Strength	450 N/mm²
Reduction of Area	45%
Elongation	30%
Modulus of Elasticity	215 000 N/mm²
Density	7.8 Kg/m3

CUTTING TOOL
The cutting tool used is brass coated carbide inserts with a tool diameter of 16mm. It consists of four teeth. It consists of very high hardness and good toughness and it is principally intended for roughing of super alloys and steel alloys. The specification of tool holder used for machining is BT30-ER16, side lock adapter system.

LUBRICANT/CUTTING FLUID
The cutting fluid used in the machining is soluble oil + water. The coolant used at mixture of 1:20 ratio i.e. is one liter of soluble oil is mixed with 2litres of water. The solubleoil of is shell dromus B Company. The capacity of the CNC tank is 40 liters.

SURFACE ROUGHNESS TESTER
Surface roughness measurement is measured using a Perthometer. The Perthometeris portable self-contained instrument for the measurement of surface texture (Ra). The parameter evaluations are microprocessor based. The measurement results are displayed on an LCD screen and can be output to an optional printer or another computer for further evaluation.

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DESIGN OF EXPERIMENTS

1.9.1. Selection Of Control Factors And Levels

A total of four process parameters with three levels are chosen as the control factors such that the levels are sufficiently far apart so that they cover wide range. The process parameter and their ranges are finalized using literature, books and machine operator's experience. The four control factors selected are spindle speed (A), feed rate (B), depth of cut(C) and coolant flow (D). EN-31 Steel alloy work pieces are used in experimentation. The machining is performed individually depending upon the lubricant conditions. The control levels and their alternativelevels are listed in table

Table No3: Control Factors And Levels

FACTORS	LEVELS		
	1	2	3
Cutting speed(v, rpm)	775	1000	1150
Feed rate(f, mm/min)	50	100	175
Depth of cut(t, mm)	0.4	1.0	1.65
Coolant rate	20	40	60

SELECTION OF ORTHOGONAL ARRAY

Selection of particular orthogonal array from the standard O.A depends on the number of factors, levels of each factor and the total degrees of freedom.

i. Number of control factors = 4
ii. Number of levels for each control factors = 3
iii. Total degrees of freedom of factors = 4x(3-1)=8
iv. Number of experiments to be conducted =9 Based on these values and the required minimum number of experiments to be conducted 9, the nearest Orthogonal Array fulfilling this condition is L9 (3^4).

Table No.4:Standard L9 (3^4) Orthogonal Array Experiment

Experiment No.	Control Factors			
	1	2	3	4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table No.5:.Experimental Design

Experiment No.	Control Factors			
	V(rpm)	F(mm/min)	t(mm)	Coolant flow
1	775	50	0.4	20
2	775	150	1.0	40
3	775	175	1.65	60
4	1000	50	1.0	60
5	1000	150	1.65	20
6	1000	175	0.4	40
7	1150	50	1.65	40
8	1150	150	0.4	60
9	1150	175	1.0	20

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PLAN OF EXPERIMENTS

The scope and objective of the present work have already been mentioned in the forgoingcases. Accordingly, the present study has been done through the following plan of experiment.

1. Checking and preparing the CNC milling ready for performing the machining operation.
2. Cutting EN-31 Steel alloy plates by power saw and performing initial end milling operation in CNC milling to get desired dimension of the work pieces.
3. Selection of appropriate tool depending upon the cutting parameters i.e. speed, feed, depth of cut and material diameter and coolant flow is done depending upon the experiment design
4. Cutting parameters speed, feed, and depth cut are selected going through the study of different literature and also in the view of machine standard specifications.
5. Performing face milling operation on EN-31 specimens in various milling environments involving lubricant conditions and various combinations of process control parameters like: speed, feed, depth of cut.
6. Measuring surface roughness and surface profile with the help of a portable stylus-type Perthometer

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PROGRAM USED FOR MACHINING:
MAIN PROGRAM:
G17G9
G75X0Y0Z0
M03S796
G00G90G54X-24.5Y-24.5
G00Z15
G01Z0F50
M08
L15P2
G00Z10
G75X0Y0Z0
M05
M09
M30
SUB PROGRAM:
G90X-24.5Y-24.5
G90X-24.5Y24.5
G90X24.5Y24.5
G90X24.5Y-24.5
G90X-24.5Y-24.5
G90X-9.5Y-9.5
G90X-9.5Y9.5
G90X9.5Y9.5
G90X9.5Y-9.5
G90X-9.5Y-9.5
G90X-3Y-3
G90X-3Y3
G90X3Y3
G90X3Y-3
G90X-3Y-3
```

RESULTS AND DISCUSSION

EN-31 Steel alloy pieces of 45mmX45mmX15mm are prepared for conducting the experiment. Using different levels of the process parameters the specimens have been machined accordingly, depending upon speed, feed, depth of cut and coolant flow conditions. Then surface roughness is measured precisely with the help of a perthometer. The results of the experiments have been shown Table No 6. Optimization of surface roughness is carried out using Taguchi method. Confirmatory tests have also been conducted to validate optimal results.

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Table No.6: Experimental Data Related To Surface Roughness (Ra)

Exp No.	Surface Roughness(Ra)			S/N Ratio
	Trail1	Trail2	Mean	
1	1.6559	2.3320	1.99395	-6.11735
2	2.2003	1.7485	1.9744	-5.96519
3	2.2804	3.0328	3.96835	-8.57275
4	0.6075	1.6260	1.11675	-1.77959
5	1.8958	2.1895	2.04265	-6.22627
6	0.7520	1.2829	1.01745	-0.43625
7	0.5510	1.2454	0.8982	0.32775
8	0.7768	0.7730	0.7749	2.21506
9	0.5074	0.6065	0.55695	5.04944

After determining the S/N ratio values (Table 6), the effect of each Machining parameter is separated based on S/N ratio at different levels and the values of S/N ratio for each level of the controllable parameters and the effect of parameter on response (Ra) in rank wise are summarized in Table-7. Basically, large S/N ratio means it is close to good quality, thus, a higher value of the S/N ratio is desirable. From the Table-7 and Fig.2 the cutting parameters with the best level are spindle speed at level-3, feed at level-3 DOC at level-2 andcoolent flow level 1.The surface roughness (Ra) value obtained for these optimum control parameters is 0.55695µm

Table 7: S/N ratio for each level of control parameters(Response based on S/N ratio)

Level	V (rpm)	F (mm/min)	t (mm)	Coolant flow
1	-6.88510	-2.52307	-1.44618	-2.43140
2	-2.81404	-3.32546	-0.89845	-2.02456
3	2.53075	1.31985	-4.82376	2.71243
Delta	9.41585	2.00561	3.92531	0.68787
Rank	1	3	2	4

RESPONSE CURVE

Response curves are graphical representations of change in performance characteristics with the variation in machining parameter level. Figure 2 shows the response graph for four factors and three levels. From the graphical representation the peak points are chosen as the optimum levels of machining parameters, such as level two of number of pass, level one of depth of cut, level three of spindle speed, level three of feed rateThe curve showing larger amount of inclination is the most significant curve, while the curve being horizontal to the mean line has less significant effect over the surface roughness.If the curve are not parallel and crosses each other, then a powerful interaction occurs and vice-versa.

EFFECT OF CUTTING PARAMETERS ON SURFACE ROUGHNESS

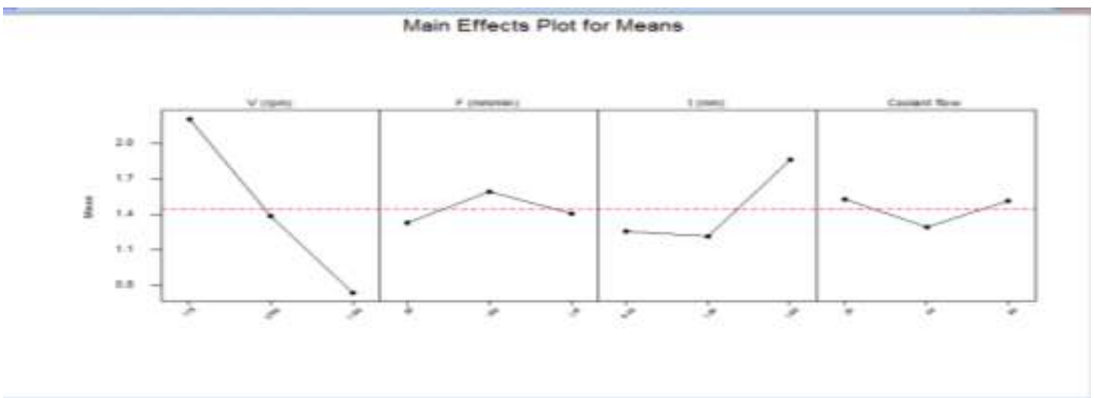

Fig-2 main effect plot for means

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From Fig No. 2, it is observed that, the surface roughness is high at low speed and certainly decreasing from moderate cutting speed to high speed conditions. Thesurface roughness is low at low feed rate and certainly increasing from low feed rate to moderate feed rate conditions, but again from moderate to high feed rate, the surface roughness decreases. Thesurface roughness is low at small depth of cut and certainly decreasing from small depth of cut to moderate depth of cut conditions, but again from moderate to high depth of cut, the surface roughness increases.

OPTIMIZATION OF CUTTING PARAMETERS

Taguchi's robust design methodology has been successfully implemented to identify the optimum settings for control parameters in order to reduce the surface roughness of the selected work piece material for their improved performance, after analysis of data from the robust design experiment the optimum setting are found is tabulated in Table No.8. it is concluded that the results are within the acceptable limits of the predicted value and can be implemented in the real time application.

Table 8:Optimum Parameters for SurfaceRoughness

Factors	**Optimum values**
Cutting Speed(rpm)	1150
Feed Rate(mm/min)	175
Depth of Cut(mm)	1.0
Coolant Flow(lit/min)	20

Table 9: Test Results

Surface Roughness(Ra) Values			**S/N Ratio**
1	2	**Average**	
0.5074	0.6065	0.55695	5.04944

CONCLUSION

It has been observed that, Taguchi's orthogonal array provides a large amount of information in a small amount of experimentation. All the four parameters are predominantly contributing to the response and all have beenconsidered. Optimum machining parameter combination has beenfound through Taguchi technique Among the consider parameters, speed has the most influence on the surface finish of the work-piece .In the present experimentation the optimum speed obtained using tauguchi technique is 1150rpm. Similarly the results obtained for feed and depth of cut are 175m/min and 1mm respectively. Hence it can be concluded that the parameters obtained are valid and within the range of EN31 machining standards. The corresponding Optimum coolant flow is 20lts/min The S/N ratio of predicted value and verification test values are valid when compare with the optimum values. It is found that S/N ratio value of verification test is within the limits of the predicted value and the objective of the work is full filled.

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